Appendix A

ELECTROPHOTOGRAPHY

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VI. SPECIAL TOPICS

Investigations and inventions in the field of xerography and electrostatics have uncovered some interesting aspects of photoconductive materials and electrostatic images which go beyond the conventional processes as we observe them in photocopy applications t Some of these seem destined to broaden the scope and usefulness of electrophotographic processes and to provide new avenues for exploration in the future

61 *Auxiliary Techniques in Xerography*

The basic steps of xerography as illustrated in Figure 1 are sensitizing exposing developing transferring fixing and cleaning t These steps are essen tial when the photoconductive surface is reused repeatedly to produce prints When electrophotographic paper is used as in Electrofax the transfer and cleaning steps are of course omitted

In the recycling of photoconductive materials such as amorphous selenium various effects and advantages can be obtained byinserting certain auxiliary steps Primarily these are reverse polarity charging and supplementary illumination

6L1 REVERSE POLARITY CHARGING Xerography with selenium plates or drums utilizes positive charging in the sensitizing step and the image formed consists of a pattern of positive surface charges Experiments have shown that certain beneficial effects may be obtained by inserting reverse polarity or negative charging prior to transfer cleaning or sensitizing

In development a negatively charged toner adheres to a positively charged image The positive charge applied to the paper in the transfer step overcomes the image attraction for the top layers of toner and these are transferred to the paper However the more tightly held toner layers close to the selenium surface are not transferred If additional negative charge is applied to the toner just prior to the transfer step more toner will be transferred

This will provide a more dense image than is normally obtained on prints and may have certain advantages such as in transfer to vellum for recopying by the diazo method

Normally after electrostatic transfer the lower layers of the toner image remain on the selenium plate and these must be cleaned from the surface prior to reuse It has been found that application of negative charging to the selenium surface just prior to cleaning will aid in the cleaning operation by making the toner easier to remove [95]

Reverse polarity charging just prior to re sensitizing has been found to be effective in reducing fatigue [96]

These auxiliary charging operations are generally not needed in the conventional xerographic processes. Care must be exercised in their use. Overcharging with reverse polarity may have adverse effects on image quality, and severe overcharging may damage the photoconductive surface.

6.1.2 SUPPLEMENTARY ILLUMINATION. Flooding the photoconductive surface at various stages in the xerographic process can have beneficial results in certain applications. The most common usage of this auxiliary step is just prior to sensitizing, where flooding with light will remove any remnants of the old electrostatic image as well as any spurious charges acquired during the transfer and cleaning steps.

Exposure of the photoconductive surface to infrared light just prior to sensitizing can aid in reducing fatigue. However, the exposure must be carefully controlled to avoid overheating of the surface. In the case of selenium, overheating may cause deterioration by crystallizing the amorphous material. Exposure of selenium plates with infrared heat lamps prior to re-use is included as a routine operation in xeroradiography. In this case, the plate is cooled immediately with a blast of forced air.

Exposure of the plate surface just prior to cleaning can result in easier removal of toner. While toner particles are generally opaque, a certain amount of scattered light gets under the edges of particles and partially discharges the image. With toners that transmit light, this procedure would, of course, be more effective.

6.2. *Latent Image Transfer in Xerography (Tesi Processes)*

In xerography the latent image consists of electrostatic surface charges. Walkup[97] found that these surface charge images can be transferred to, or reproduced upon, other dielectric surfaces. The techniques for accomplishing charge transfer are referred to as TESI processes, from Transfer of Electro-Static Images. Thus, xerography becomes the first photographic process where latent images, prior to development, can be reproduced on other surfaces.

The material to which the electrostatic image is transferred must, of course, be capable of retaining the image; i.e., it must be a good insulator. Plastics, such as Mylar,* polystyrene and polyethylene are examples. Electrostatic images can also be transferred to dielectric coated papers.

The transferred image can be developed by the same methods used for developing the electrostatic images formed directly on photoconductive surfaces. However, since the charge on the dielectric surface is not dissipated by exposure to light, it is not necessary to shield the image from light during development.

Trademark: E. I. DuPont Company.

The transfer of latent electrostatic images can be accomplished by a number of different techniques. Several of these are described below. Numbers have been assigned to these techniques by the author. The numbers serve only as a means of identifying the different techniques for discussion purposes.

The TESI processes can be divided into two classes:

1. TEST processes wherein the electrostatic image is first formed on the surface of a photoconductive insulator, such as a xerographic plate, and subsequently transferred to a dielectric surface.
2. TESI processes wherein the electrostatic image is formed while the dielectric film is in contact with the electrophotographic plate.

The various techniques of electrostatic image transfer are described below. in some of the figures illustrating these techniques, the surfaces will be shown separated by an air gap. It should be understood that this air gap may be quite small and may exist even when the surfaces are in virtual contact. All TEST processes require the mechanical operation of bringing two surfaces into contact and subsequently separating them. One surface, of course, is the dielectric to which the electrostatic image is transferred ; the other is the image-bearing or image-forming surface.

The explanations and figures that follow are intended primarily to illustrate basic operations in simplified form. For this reason the descriptions are limited to charge transfer between flat surfaces. In actual practice the image may be transferred from the surface of a drum.

6.3. *Tesi Processes Utilizing Previously Formed Electrostatic Images*

6.3.1 TEST TECHNIQUE NO. 1. This is the original technique proposed by Walkup.[97] The essential elements are shown in Figure 51. The procedure is as follows :

1. An electrostatic image is produced on a xerographic plate by conventional methods. When this plate is amorphous selenium, the polarity of the image charge will be positive. The image is indicated by the plus charges in Figure 51.
2. A dielectric film, coated on one side with conductive material, is brought into contact with the plate surface. (Mylar, aluminized on one side, is an example of the type of dielectric film that could be used.)
3. The switch A, Figure 51, is then closed so that a negative potential is applied to the conductive coating of the dielectric film. The voltages applied between the two electrodes may be of the order of 1000-2000 volts.
4. The two surfaces are then separated, the voltage between the electrodes being maintained during separation. At a critical point during separation,

just prior to air breakdown, a discharge current will flow across the gap in the region of the image. This produces a positively charged mirror image of the original electrostatic image on the surface of the dielectric.

5. After the surfaces have been separated, switch A is opened and switch B closed, so that the conductive backing is reduced to ground potential.

It will be obvious, of course, that negatively charged electrostatic images can be transferred in a similar manner by reversing the polarity of the voltage

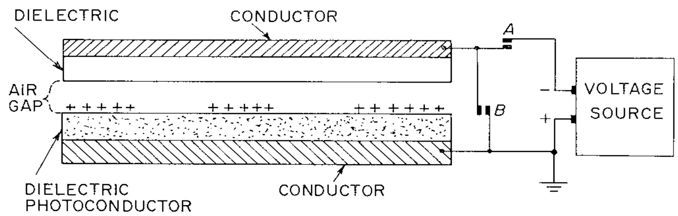

Fig. 51 Diagram of TESI Technique No. 1.

applied between the conductive bases of the dielectric and the electrophotographic plate.

It should be pointed out that, since the applied voltage remains constant during separation of the two surfaces, the field intensity in the air gap due to this source will diminish as the gap width increases.

A variation of this technique is described in a patent issued to Fotland and

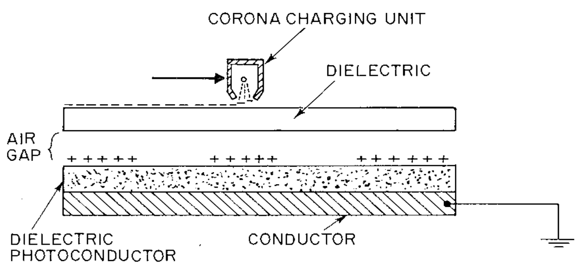

Fig. 52 Diagram of TESI Technique No. 2.

Mayer [98] The variation consists of filling the air gap with a dielectric liquid which is applied as a liquid film on the xerographic plate Greater resolution of the transferred image is claimed

632 TEST TECHNIQUE NO This technique has been described by Carlson and Bogdonoff[99] and is somewhat of a variation on Technique No 11 The primary differences are that a dielectric film without a conductive backing can be used and the transfer potential is applied to the dielectric with a corona charging unit The procedure is outlined below and illustrated in Figure 52

1. An electrostatic image is formed on the xerographic plate as in Technique No. 1.
2. A dielectric film is placed on the top of the photoconductive layer.
3. A negative charge is applied over the top surface of the dielectric by passing a corona charging unit over the surface.
4. The surfaces are then separated, charge transfer taking place as the air gap approaches the critical width for air breakdown in the image area.
5. After separation, negative charge on the top side of the dielectric can be removed by corona charging with the opposite polarity or by wiping this surface with a wet cloth, or by other means.

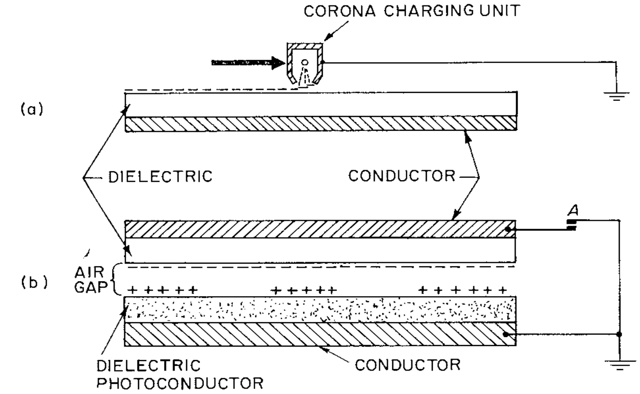

Fig. 53 Diagram of TESI Technique No. 3.

This technique produces the same type of image as in Technique No. 1, i.e., a positively charged, photopositive mirror image of the image on the photoconductor surface.

Since the charge applied to the outer surface of the dielectric remains constant during separation of the surfaces, the field in the air gap due to this charge will remain essentially constant. This is the main difference between Techniques No. 1 and No. 2.

6.3.3 TESL TECHNIQUE NO. 3. This technique provides a method of obtaining image reversal* by charge transfer.

The method as demonstrated at the IBM laboratories in San Jose, California, is outlined below and illustrated in Figure 53.

1. An electrostatic image is formed on a xerographic plate by conventional methods. The image on the photoconductor surface is positively charged in this case.

* Negative to positive or vice versa.

2. A dielectric film with a conductive base is charged uniformly with negative charges on the dielectric side, using a corona charging unit as shown in Figure 53a.
3. The charged dielectric film is then flipped over and placed on top of the electrostatic image on the plate surface. (Figure 53b.)
4. Switch A is then closed, bringing both electrodes to ground potential. Since the potential difference between the conductive substrates is now zero, the voltage across the air gap in the image area will be determined by the combined potentials of the positively charged image and the negatively charged dielectric.
5. The surfaces are then separated, image transfer taking place during separation.

The charge transferred in this case neutralizes negative charge on the dielectric in the area opposite the original electrostatic image. Thus, the electrostatic image on the dielectric consists of neutralized areas on a negatively charged background. If this image is developed with a positively charged toner a reversal of the original image is obtained. It is also possible, by proper selection of applied voltage, image charge, and the charge on the dielectric to obtain an image of one polarity and a background of the opposite polarity.

It is obvious, of course, that this method can also be used to produce transferred images from negatively charged electrostatic images. In this case the dielectric film would be charged to a positive polarity.

6.3.4 TESL TECHNIQUE NO. 4. A different approach to the generation of electrostatic images on dielectric films has been described by Dreyfoos, Mazza, Radke, and Staley.[100] This technique differs in principle from those previously described inasmuch as it is not strictly a charge transfer process. The image is reproduced as a charge pattern on the outer surface of the dielectric film. The essential elements are shown in Figure 54 (a), and the procedure is as follows :

1. A positively charged electrostatic image is first produced on a xerographic plate.
2. A dielectric film is then placed on the plate surface and in intimate contact with the surface.
3. A positive charge is then applied to the top side of the dielectric film with a corona charging unit. A "scorotron" charging unit is indicated in Figure 54 (a), since this type of charging unit would seem to be most suitable for the process.
4. The dielectric film is then stripped from the xerographic plate.

The image reproduced on the dielectric film will consist of areas of somewhat depleted charge surrounded by a uniform background of positive charges. The reason is as follows : The electrostatic image on the photoconductor

surface produces a positive potential at the top side of the dielectric which is less than that of the image at the photoconductor surface. If the scorotron unit is adjusted to apply a positive charge of uniform potential over the surface of the dielectric, less charge will be deposited on the area above the image. It is a virtue of the scorotron charging method that a charge of uniform potential, rather than uniform charge density, is applied to the surface. This potential can be controlled by biasing the screen grid to the approximate potential desired.

Two variations of this technique are suggested. These are illustrated in Figure 54 (b) and 54 (c). In Figure 54 (b) the steps are the same as in Figure

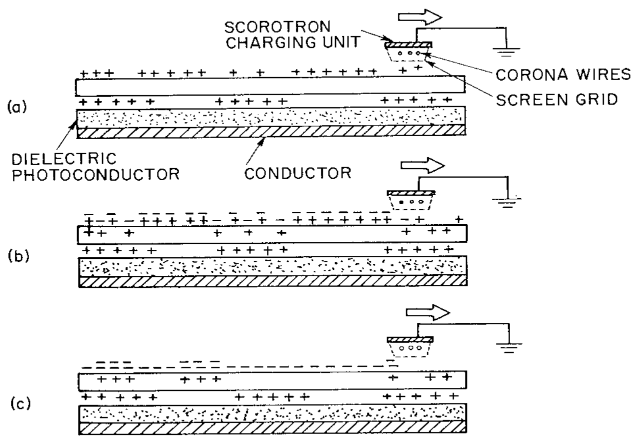

Fig. 54 Diagram of TESI Technique No. 4.

54 (a), except that the positive charging is followed immediately by negative charging, to a uniform potential, just sufficient to neutralize the positive charges in the background areas. Then, after stripping the dielectric film from the plate surface, the images will consist of negatively charged areas with a neutral background.

In Figure 54 (c) the steps are the same as in Figure 54 (a), except that negative charging is used instead of positive charging. This produces an image with a greater density of negative charge than the surrounding background.

6.4. *Tesi Processes Including Image Formation*

Several techniques can be used to produce electrostatic images on a dielectric surface while the dielectric film is in contact with a xerographic plate. The general procedure is to expose the xerographic plate either by projecting the image through a dielectric film with a transparent conductive backing or by

using a xerographic plate with a transparent base and exposing through the base. Electrical stress is applied across the dielectric and the xerographic plate during exposure. The techniques, known to the author, are described below.

6.4.1 TEST TECHNIQUE NO. 5. This technique is described in a patent issued to L. E. Walkup.[10] One form of the process is illustrated in Figure 55. The procedure is as follows :

1. A transparent dielectric film with a transparent conductive backing is placed over a xerographic plate so that the dielectric surface is in contact with the plate surface.
2. The transparent conductor is electrically connected to the conductive

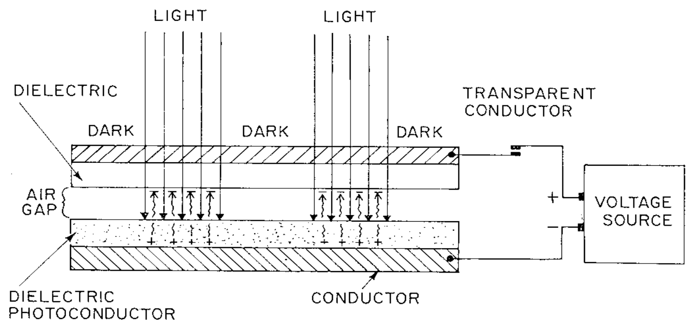

Fig. 55 Diagram of TESI Technique No. 5.

base of the plate through a high-voltage source (up to several thousand volts). Simultaneously an optical image is projected onto the plate surface.
3. After a brief exposure to light and electrical stress, the light is turned off. The dielectric film is then separated from the photoconductor surface, the electrical stress being maintained during separation.

The image produced on the dielectric by this procedure consists of neutral areas in the dark portions and charges in the illuminated areas.

It will be understood that either a positive or negative charge can be produced on the dielectric surface depending on the polarity of the applied potential.

Also, it should be mentioned that a transparent conductor, such as Nesa* glass, could be used as a substrate for the photoconductor. In this case the optical image could be projected through the back of the xerographic plate. In this technique the photoconductive material does not necessarily have to be a good insulator in the dark. Thus, some of the more sensitive photoconductors might be used.

* Trademark: Pittsburgh Plate Glass Co.

6.4.2 TESI TECHNIQUE NO. 6. This technique has been described in the patent issued to Dreyfoos et al."° One form of the process is illustrated in Figure 56. The procedure is as follows :

1. The dielectric film is placed over the surface of a xerographic plate and charged to a uniform potential, in this case with a positive charge.
2. The xerographic plate is then exposed to an optical image by projection through the dielectric film.
3. After exposure to the optical image, a negative charge of uniform potential is applied to the dielectric surface.
4. The dielectric film can then be removed from the xerographic plate.

The image produced on the dielectric in this case will consist of positive charges

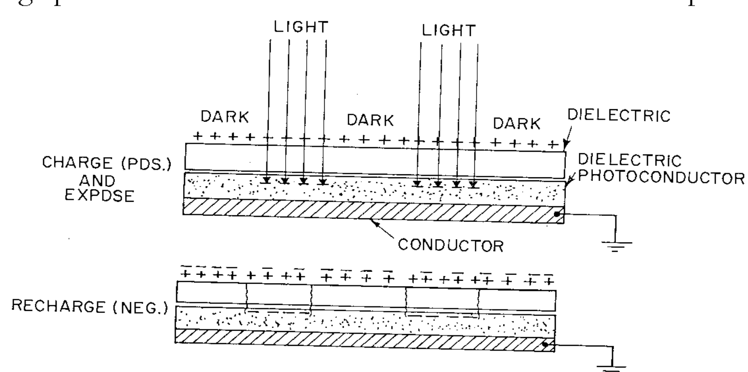

Fig. 56 Diagram of TESI Technique No. 6.

in the areas where the photoconductor is exposed to light, and neutral areas elsewhere.

After exposure to light the photoconductor will become conductive, negative charges accumulating at the top surface of the photoconductor, and positive charges flowing to the conductive base (see Figure 56). This reduces the positive potential on the top surface of the dielectric opposite the exposed areas on the plate. Subsequent charging of the dielectric surface to a uniform negative potential with respect to the conductive base will then result in less neutralization of positive charges in the lighted areas. The result is a net positive charge in these areas.

6.4.3 TESI TECHNIQUE NO. 7. This technique is somewhat similar to No. 3 (see Figure 53). It may be thought of as a combination of No. 3 and No. 5. The steps, illustrated in Figure 57, are as follows :

1. A transparent dielectric film, with a transparent conductive base is charged to a negative polarity with a corona unit.

2. The dielectric film is then placed on top of a xerographic plate with the charged side down.
3. Switch A (Figure 57) is then closed, and at the same time, the plate surface is exposed to an optical image which is projected through the dielectric film.
4. After exposure, the dielectric film is removed from the photoconductor surface, the switch remaining closed during separation.

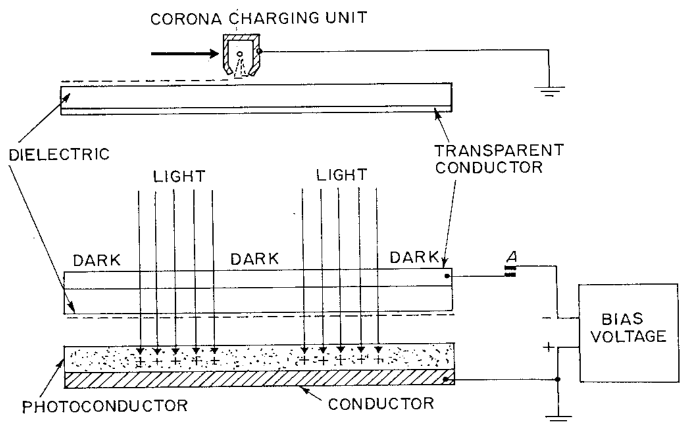

Fig. 57 Diagram of TESI Technique No. 7.

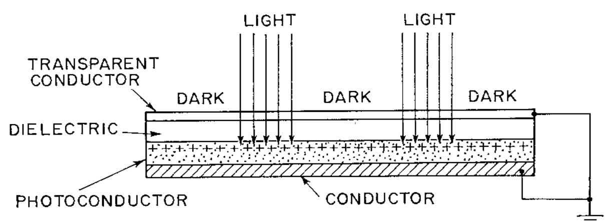

Fig. 58 Arrangement for direct transfer of electrostatic images.

The image produced on the dielectric will be negatively charged areas surrounded by a more or less neutral background, since the light-exposed areas transfer charges in this process. The photoconductor becomes polarized during exposure, so that the surface adjacent to the dielectric becomes positively charged. This increases the field across the air gap in the illuminated areas. Charge transfer in these areas results in neutralization of charges on the dielectric surface.

A bias voltage (Figure 57) is included in the circuit between the conductive

bases to boost the field across the air gap. This may not be necessary if the field intensity due to the negative charge is large. In this case, direct connection between the two conductive bases will be sufficient.

6.5. *Direct Transfer of Surface Charge Images*

The author and R. Meline found that it is possible to obtain direct transfer of surface charges from one surface to another when the surfaces are placed together in intimate contact. To achieve this it is necessary to eliminate the air gap, a condition which generally requires application of pressure. The procedure is as follows :

1. A uniform charge is applied to the surface of a photoconductive insulator, such as amorphous selenium.
2. A transparent dielectric sheet with a transparent conductive backing is brought into pressure contact with the photoconductor, as shownin Figure 58.
3. The conductive backings of the two layers are then electrically connected, and the photoconductor is exposed to an optical image through the transparent dielectric.
4. After exposure the dielectric sheet is removed.

After separation of the two surfaces an electrostatic image will be present on each surface, although one will be a mirror image of the other. The surface charges will be divided so that equal voltages are retained across both the dielectric sheet and the photoconductive layer.

Actually the surface charge, applied prior to bringing the surfaces together, could be applied to either the dielectric surface or the photoconductor, or both.

The process can be used to form electrostatic images on opaque dielectric materials if a transparent conductive base is used for the photoconductive layer. In this case, exposure would be through the transparent base.

Alternatively, the charged photoconductive layer can be exposed to the image prior to bringing the surfaces into contact. In this case, charge is applied only to the photoconductor surface.

This technique is capable of retaining very high resolution in electrostatic images. Since image transfer takes place while the two surfaces are in contact, image spreading is essentially eliminated.